Cloud Optimized GeoTIFF (COG) File Format

Status of this Memo

This RFC provides information to the NASA Earth Science community. This RFC describes an Earth Science Data Systems (ESDS) standard. Distribution of this memo is unlimited.

Change Explanation

V1.1 Updated to reflect final publication of *OGC Cloud Optimized GeoTIFF Standard*, Version 1.0 by the Open Geospatial Consortium (https://docs.ogc.org/is/21-026/21-026.html).

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Abstract

This document designates the Cloud Optimized GeoTIFF (COG) file format as a standard for NASA Earth science data systems. COG is an extension of the mature, well-established, and heavily used GeoTIFF file format, accepted as a NASA standard in 2019. The Open Geospatial Consortium (OGC) approved version 1.0 of the *OGC Cloud Optimized GeoTIFF Standard* in July 2023. Also following the Cloud Optimized GeoTIFF (COG) published as official OGC Standard in October 2023. Support for COG is growing in the geospatial software community and usage within NASA is starting as well.

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1 Introduction

The Tagged Image File Format (TIFF) was developed in 1996 by Microsoft and Aldus. Aldus later merged with Adobe, the current copyright holder of the TIFF specification [2]. GeoTIFF builds on the TIFF format by using the TIFF extension mechanism to add tags that embed geographic information, hence the name Geographic Tagged Image File Format (GeoTIFF). The Cloud Optimized GeoTIFF (COG) relies on two characteristics of the TIFF v6 format (tiles and reduced resolution subfiles), GeoTIFF keys for georeference, and the HTTP range, which allows for efficient downloading of parts of imagery and grid coverage data on the web and to make fast data visualization of TIFF or BigTIFF files and fast geospatial processing workflows possible.

1.1 Background

GeoTIFF has already been approved as a NASA/ESDS standard, COG introduces new capabilities but is backwards compatible. The additional capabilities to allow only part of the file to be accessed enhances cloud usage without impacting legacy tools.

1.2 Evidence of Implementation

1.2.1 COG data

COG formatted data are available from NASA Earth science data providers. Examples can be seen below.

LP DAAC:

HLSL30.002 - https://doi.org/10.5067/HLS/HLSL30.002 (C2021957657-LPCLOUD)
HLSS30.002 - https://doi.org/10.5067/HLS/HLSS30.002 (C2021957295-LPCLOUD)
ECO_L2T_LSTE.002
- https://doi.org/10.5067/ECOSTRESS/ECO_L2T_LSTE.002 (C2076090826-LPCLOUD)
ECO_L1CT_RAD - https://doi.org/10.5067/ECOSTRESS/ECO_L1CT_RAD.002 (C2595678301-LPCLOUD)
OPERA_L3_DIST-ALERT-HLS_PROVISIONAL_V0 - https://doi.org/10.5067/SNWG/OPERA_L3_DIST-ALERT-HLS_PROVISIONAL_V0.000 (C2517904291-LPCLOUD)

1.2.2 COG software

COG support among major geospatial software and programming language specific libraries is well established and continues to grow. Below is a sample of some of the most well-known examples.

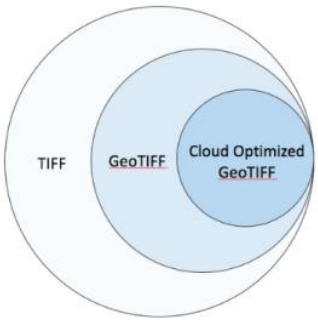
- QGIS 3.2 has stellar COG support, with an option to select online files in the data import, including authentication for private data (tutorial coming soon). Older versions can read Cloud Optimized GeoTIFF's files using Virtual Raster Builder with a vsicurl file format to refer to the online URL. See the tutorial for details.
- GDAL supports the creation of COG file with Cloud Optimized GeoTIFF Generator
- Earth Observing System Engine and Land Viewer are both able to leverage Cloud Optimized GeoTIFF files for live web tile serving and on the fly band math.
- Rasterio (Python Library) Plugins:
    - Rio-cogeo create and validate COGs
    - Rio-tiler read tiles from COGs
    - Rio-glui explore COGs on a web-browser.

- Google Earth Engine now supports *output* of COGs from any Earth Engine operation, see: Exporting - Configuration Parameters. Earth Engine supports reading COG data hosted on Google Cloud Storage, see: COG-backed Earth Engine Assets.
- GRASS GIS can read Cloud Optimized GeoTIFFs by using Virtual Raster Builder with a vsicurl file format to refer to the online URL and registration within GRASS GIS using r.external.
- GeoServer can leverage S3-hosted COGs by using the COG Support community module.
- RasterFrames brings the power of Spark DataFrames to geospatial raster data and is able to read Cloud Optimized GeoTIFFs using GeoTrellis.
- GeoTiffCOG C# is a C# Library for querying GeoTiff files, including Cloud Optimized GeoTIFFs.

1.2.3 Related work

2 COG File Structure

The COG data format builds on the established GeoTIFF format. Similar to how GeoTIFF built off the existing standard TIFF images by adding geo-referencing information, COG builds off of GeoTIFF to add features needed to optimize data use in a cloud-based environment.

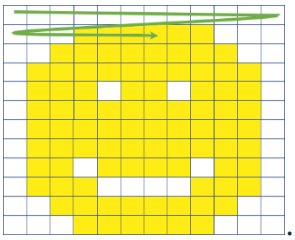


A COG file is a TIFF file as specified by the current TIFF specification, version 6.0 [2].
Thus, the files are compatible with existing software and libraries that can handle TIFF format, such as Photoshop and the *libtiff* library. TIFF provides the ability to define tags that can carry information not previously defined in the TIFF format. The information in these tags is ignored by standard TIFF software but can be used by other software.

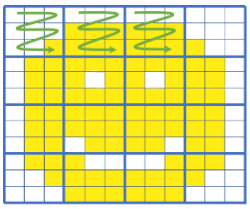
Cloud Optimized GeoTIFF relies on two complementary pieces of technology.

> The first is the ability of a GeoTIFF to not only store the raw pixels of the image, but to also organize those pixels in ways that are more efficient for cloud storage and retrieval.

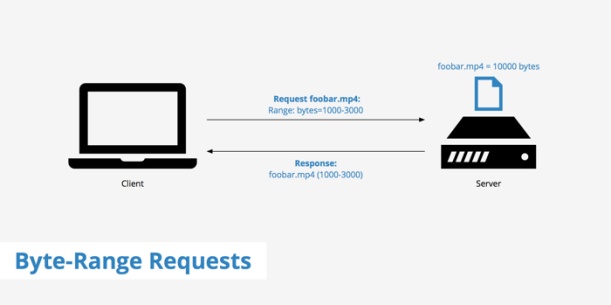
Traditional row by row organization



COG tile organization



The second is HTTP GET range requests, that let clients ask for just the portions of a file that they need. Together these enable fully online processing of data by COG-aware clients, as they can stream the right parts of the GeoTIFF as they need it, instead of having to download the whole file.



GeoTIFF uses a small set of these TIFF tags to store georeferencing information. All GeoTIFF tags can be accessed by any other software, nothing is stored in a way that would hide the information.

3 Interoperability and Applicability Considerations

COG is not necessarily suitable for every data type. There are other scientific file formats that are well established within the NASA community, e.g., HDF5 and netCDF, that are approved for use in NASA Earth science data systems.

However, there is continued interest and demand for the COG file format, primarily as a distribution format for satellite via a cloud-computing based distribution system. COG's capabilities allow for reduced data volume transfers from cloud-based systems to legacy data storage.

4 Future versions of the specification

Users of this version (1.1) of the COG specification should be aware that the specification is under continued development within the OGC. Future versions may introduce changes that could be incompatible with current use. The specification itself contains notes identifying areas that are likely to be revised in future versions.

5 References

5.1 Normative References

[1] **OGC GeoTIFF Standard**, OGC Document 21-026, July 14, 2023
https://docs.ogc.org/is/21-026/21-026.html

5.2 Informative References

[2] Adobe Systems Incorporated. *TIFF Revision 6.0 Final,* June 3, 1992, https://www.adobe.io/open/standards/TIFF.html

[3] OGC GeoTIFF Reference: https://www.ogc.org/standard/geotiff/

[4] Cloud Optimized GeoTIFF http://www.cogeo.org/

6 Authors' Addresses

ESDIS Standards Coordination Office (ESCO)
Email: esco-staff@lists.nasa.gov
Web: https://earthdata.nasa.gov/esdis/esdis-standards-office-esco

Appendix A Glossary of acronyms

COG	Cloud Optimized GeoTIFF
DAAC	Distributed Active Archive Center
DEM	Digital Elevation Model
EPSG	European Petroleum Survey Group (Now the International Association of Oil & Gas Producers)
TIFF	Tagged Image File Format
GDAL	Geospatial Data Abstraction Library
GeoTIFF	Geographic Tagged Image File Format
ESDS	Earth Science Data Systems
HDF	Hierarchical Data Format
HTTP	Hypertext Transport Protocol
JPL	Jet Propulsion Laboratory
NASA	National Aeronautics and Space Administration
NetCDF	Network Common Data Form
OGC	Open Geospatial Consortium
ORNL	Oak Ridge National Laboratory
RFC	Request for Comments
SEDAC	Socioeconomic Data and Applications Center
SWG	Standards Working Group